However, the epidemic dies out for any of several reasons, such as being cured by modern medicine, or being stopped when everybody around has already been infected and either becomes immune or dies. For example, a previously unknown fever termed O'nyong-nyong fever appeared in East Africa in 1959 and proceeded to infect several million Africans. It probably arose from a virus of monkeys and was transmitted to humans by mosquitoes. The fact that patients recovered quickly and became immune to further attack helped the new disease die out quickly. Closer to home for Americans, Fort Bragg fever was the name applied to a new leptospiral disease that broke out in the United States in the summer of 1942 and soon disappeared.

A fatal disease vanishing for another reason was New Guinea's laughing sickness, transmitted by cannibalism and caused by a slow-acting virus from which no one has ever recovered. Kuru was on its way to exterminating New Guinea's Foré tribe of 20,000 people, until the establishment of Australian government control around 1959 ended cannibalism and thereby the transmission of kuru. The annals of medicine are full of accounts of diseases that sound like no disease known today, but that once caused terrifying epidemics and then disappeared as mysteriously as they had come. The "English sweating sickness," which swept and terrified Europe between 1485 and 1552, and the "Picardy sweats" of 18th- and 19th-century France, are just two of the many epidemic illnesses that vanished long before modern medicine had devised methods for identifying the responsible microbes.

A third stage in the evolution of our major diseases is represented by former animal pathogens that did establish themselves in humans, that have not (not yet?) died out, and that may or may not still become major killers of humanity. The future remains very uncertain for Lassa fever, caused by a virus derived probably from rodents. Lassa fever was first observed in 1969 in Nigeria, where it causes a fatal illness so contagious that Nigerian hospitals have been closed down if even a single case appears. Better established is Lyme disease, caused by a spirochete that we get from the bite of ticks carried by mice and deer. Although the first known human cases in the United States appeared only as recently as 1962, Lyme disease is already reaching epidemic proportions in many parts of our country. The future of AIDS, derived from monkey viruses and first documented in humans around 1959, is even more secure (from the virus's perspective).

The final stage of this evolution is represented by the major, long-established epidemic diseases confined to humans. These diseases must have been the evolutionary survivors of far more pathogens that tried to make the jump to us from animals—and mostly failed.

What is actually going on in those stages, as an exclusive disease of animals transforms itself into an exclusive disease of humans? One transformation involves a change of intermediate vector: when a microbe relying on some arthropod vector for transmission switches to a new host, the microbe may be forced to find a new arthropod as well. For example, typhus was initially transmitted between rats by rat fleas, which sufficed for a while to transfer typhus from rats to humans. Eventually, typhus microbes discovered that human body lice offered a much more efficient method of traveling directly between humans. Now that Americans have mostly deloused themselves, typhus has discovered a new route into us: by infecting eastern North American flying squirrels and then transferring to people whose attics harbor flying squirrels.

In short, diseases represent evolution in progress, and microbes adapt by natural selection to new hosts and vectors. But compared with cows' bodies, ours offer different immune defenses, lice, feces, and chemistries. In that new environment, a microbe must evolve new ways to live and to propagate itself. In several instructive cases doctors or veterinarians have actually been able to observe microbes evolving those new ways.

The best-studied case involves what happened when myxomatosis hit Australian rabbits. The myxo virus, native to a wild species of Brazilian rabbit, had been observed to cause a lethal epidemic in European domestic rabbits, which are a different species. Hence the virus was intentionally introduced to Australia in 1950 in the hopes of ridding the continent of its plague of European rabbits, foolishly introduced in the nineteenth century. In the first year, myxo produced a gratifying (to Australian farmers) 99.8 percent mortality rate in infected rabbits. Unfortunately for the farmers, the death rate then dropped in the second year to 90 percent and eventually to 25 percent, frustrating hopes of eradicating rabbits completely from Australia. The problem was that the myxo virus evolved to serve its own interests, which differed from ours as well as from those of the rabbits. The virus changed so as to kill fewer rabbits and to permit lethally infected ones to live longer before dying. As a result, a less lethal myxo virus spreads baby viruses to more rabbits than did the original, highly virulent myxo.

For a similar example in humans, we have only to consider the surprising evolution of syphilis. Today, our two immediate associations to syphilis are genital sores and a very slowly developing disease, leading to the death of many untreated victims only after many years. However, when syphilis was first definitely recorded in Europe in 1495, its pustules often covered the body from the head to the knees, caused flesh to fall off people's faces, and led to death within a few months. By 1546, syphilis had evolved into the disease with the symptoms so well known to us today. Apparently, just as with myxomatosis, those syphilis spirochetes that evolved so as to keep their victims alive for longer were thereby able to transmit their spirochete offspring into more victims.

THE IMPORTANCE OF lethal microbes in human history is well illustrated by Europeans' conquest and depopulation of the New World. Far more Native Americans died in bed from Eurasian germs than on the battlefield from European guns and swords. Those germs undermined Indian resistance by killing most Indians and their leaders and by sapping the survivors' morale. For instance, in 1519 Cortés landed on the coast of Mexico with 600 Spaniards, to conquer the fiercely militaristic Aztec Empire with a population of many millions. That Cortés reached the Aztec capital of Tenochtitlán, escaped with the loss of "only" two-thirds of his force, and managed to fight his way back to the coast demonstrates both Spanish military advantages and the initial naïveté of the Aztecs. But when Cortés's next onslaught came, the Aztecs were no longer naive and fought street by street with the utmost tenacity. What gave the Spaniards a decisive advantage was smallpox, which reached Mexico in 1520 with one infected slave arriving from Spanish Cuba. The resulting epidemic proceeded to kill nearly half of the Aztecs, including Emperor Cuitláhuac. Aztec survivors were demoralized by the mysterious illness that killed Indians and spared Spaniards, as if advertising the Spaniards' invincibility. By 1618, Mexico's initial population of about 20 million had plummeted to about 1.6 million.

Pizarro had similarly grim luck when he landed on the coast of Peru in 1531 with 168 men to conquer the Inca Empire of millions. Fortunately for Pizarro and unfortunately for the Incas, smallpox had arrived overland around 1526, killing much of the Inca population, including both the emperor Huayna Capac and his designated successor. As we saw in Chapter 3, the result of the throne's being left vacant was that two other sons of Huayna Capac, Atahuallpa and Huascar, became embroiled in a civil war that Pizarro exploited to conquer the divided Incas.

When we in the United States think of the most populous New World societies existing in 1492, only those of the Aztecs and the Incas tend to come to our minds. We forget that North America also supported populous Indian societies in the most logical place, the Mississippi Valley, which contains some of our best farmland today. In that case, however, conquistadores contributed nothing directly to the societies' destruction; Eurasian germs, spreading in advance, did everything. When Hernando de Soto became the first European conquistador to march through the southeastern United States, in 1540, he came across Indian town sites abandoned two years earlier because the inhabitants had died in epidemics. These epidemics had been transmitted from coastal Indians infected by Spaniards visiting the coast. The Spaniards' microbes spread to the interior in advance of the Spaniards themselves.

De Soto was still able to see some of the densely populated Indian towns lining the lower Mississippi. After the end of his expedition, it was a long time before Europeans again reached the Mississippi Valley, but Eurasian microbes were now established in North America and kept spreading. By the time of the next appearance of Europeans on the lower Mississippi, that of French settlers in the late 1600s, almost all of those big Indian towns had vanished. Their relics are the great mound sites of the Mississippi Valley. Only recently have we come to realize that many of the mound-building societies were still largely intact when Columbus reached the New World, and that they collapsed (probably as a result of disease) between 1492 and the systematic European exploration of the Mississippi.

When I was young, American schoolchildren were taught that North America had originally been occupied by only about one million Indians. That low number was useful in justifying the white conquest of what could be viewed as an almost empty continent. However, archaeological excavations, and scrutiny of descriptions left by the very first European explorers on our coasts, now suggest an initial number of around 20 million Indians. For the New World as a whole, the Indian population decline in the century or two following Columbus's arrival is estimated to have been as large as 95 percent.

The main killers were Old World germs to which Indians had never been exposed, and against which they therefore had neither immune nor

genetic resistance. Smallpox, measles, influenza, and typhus competed for top rank among the killers. As if these had not been enough, diphtheria, malaria, mumps, pertussis, plague, tuberculosis, and yellow fever came up close behind. In countless cases, whites were actually there to witness the destruction occurring when the germs arrived. For example, in 1837 the Mandan Indian tribe, with one of the most elaborate cultures in our Great Plains, contracted smallpox from a steamboat traveling up the Missouri River from St. Louis. The population of one Mandan village plummeted from 2,000 to fewer than 40 within a few weeks.

WHILE OVER A dozen major infectious diseases of Old World origins became established in the New World, perhaps not a single major killer reached Europe from the Americas. The sole possible exception is syphilis, whose area of origin remains controversial. The one-sidedness of that exchange of germs becomes even more striking when we recall that large, dense human populations are a prerequisite for the evolution of our crowd infectious diseases. If recent reappraisals of the pre-Columbian New World population are correct, it was not far below the contemporary population of Eurasia. Some New World cities like Tenochtitlán were among the world's most populous cities at the time. Why didn't Tenochtitlán have awful germs waiting for the Spaniards?

One possible contributing factor is that the rise of dense human populations began somewhat later in the New World than in the Old World. Another is that the three most densely populated American centers—the Andes, Mesoamerica, and the Mississippi Valley—never became connected by regular fast trade into one huge breeding ground for microbes, in the way that Europe, North Africa, India, and China became linked in Roman times. Those factors still don't explain, though, why the New World apparently ended up with no lethal crowd epidemics at all. (Tuberculosis DNA has been reported from the mummy of a Peruvian Indian who died 1,000 years ago, but the identification procedure used did not distinguish human tuberculosis from a closely related pathogen (*Mycobacterium bovis*) that is widespread in wild animals.)

Instead, what must be the main reason for the failure of lethal crowd epidemics to arise in the Americas becomes clear when we pause to ask a simple question. From what microbes could they conceivably have evolved? We've seen that Eurasian crowd diseases evolved out of diseases

of Eurasian herd animals that became domesticated. Whereas many such animals existed in Eurasia, only five animals of any sort became domesticated in the Americas: the turkey in Mexico and the U.S. Southwest, the llama / alpaca and the guinea pig in the Andes, the Muscovy duck in tropical South America, and the dog throughout the Americas.

In turn, we also saw that this extreme paucity of domestic animals in the New World reflects the paucity of wild starting material. About 80 percent of the big wild mammals of the Americas became extinct at the end of the last Ice Age, around 13,000 years ago. The few domesticates that remained to Native Americans were not likely sources of crowd diseases, compared with cows and pigs. Muscovy ducks and turkeys don't live in enormous flocks, and they're not cuddly species (like young lambs) with which we have much physical contact. Guinea pigs may have contributed a trypanosome infection like Chagas' disease or leishmaniasis to our catalog of woes, but that's uncertain. Initially, most surprising is the absence of any human disease derived from llamas (or alpacas), which it's tempting to consider the Andean equivalent of Eurasian livestock. However, llamas had four strikes against them as a source of human pathogens: they were kept in smaller herds than were sheep and goats and pigs; their total numbers were never remotely as large as those of the Eurasian populations of domestic livestock, since llamas never spread beyond the Andes; people don't drink (and get infected by) llama milk; and llamas aren't kept indoors, in close association with people. In contrast, human mothers in the New Guinea highlands often nurse piglets, and pigs as well as cows are frequently kept inside the huts of peasant farmers.

THE HISTORICAL IMPORTANCE of animal-derived diseases extends far beyond the collision of the Old and the New Worlds. Eurasian germs played a key role in decimating native peoples in many other parts of the world, including Pacific islanders, Aboriginal Australians, and the Khoisan peoples (Hottentots and Bushmen) of southern Africa. Cumulative mortalities of these previously unexposed peoples from Eurasian germs ranged from 50 percent to 100 percent. For instance, the Indian population of Hispaniola declined from around 8 million, when Columbus arrived in A.D. 1492, to zero by 1535. Measles reached Fiji with a Fijian chief returning from a visit to Australia in 1875, and proceeded to kill about one-quarter of all Fijians then alive (after most Fijians had already been

killed by epidemics beginning with the first European visit, in 1791). Syphilis, gonorrhea, tuberculosis, and influenza arriving with Captain Cook in 1779, followed by a big typhoid epidemic in 1804 and numerous "minor" epidemics, reduced Hawaii's population from around half a million in 1779 to 84,000 in 1853, the year when smallpox finally reached Hawaii and killed around 10,000 of the survivors. These examples could be multiplied almost indefinitely.

However, germs did not act solely to Europeans' advantage. While the New World and Australia did not harbor native epidemic diseases awaiting Europeans, tropical Asia, Africa, Indonesia, and New Guinea certainly did. Malaria throughout the tropical Old World, cholera in tropical Southeast Asia, and yellow fever in tropical Africa were (and still are) the most notorious of the tropical killers. They posed the most serious obstacle to European colonization of the tropics, and they explain why the European colonial partitioning of New Guinea and most of Africa was not accomplished until nearly 400 years after European partitioning of the New World began. Furthermore, once malaria and yellow fever did become transmitted to the Americas by European ship traffic, they emerged as the major impediment to colonization of the New World tropics as well. A familiar example is the role of those two diseases in aborting the French effort, and nearly aborting the ultimately successful American effort, to construct the Panama Canal.

Bearing all these facts in mind, let's try to regain our sense of perspective about the role of germs in answering Yali's question. There is no doubt that Europeans developed a big advantage in weaponry, technology, and political organization over most of the non-European peoples that they conquered. But that advantage alone doesn't fully explain how initially so few European immigrants came to supplant so much of the native population of the Americas and some other parts of the world. That might not have happened without Europe's sinister gift to other continents—the germs evolving from Eurasians' long intimacy with domestic animals.

CHAPTER 12

BLUEPRINTS AND BORROWED LETTERS

NINETEENTH-CENTURY AUTHORS TENDED TO INTERPRET history as a progression from savagery to civilization. Key hallmarks of this transition included the development of agriculture, metallurgy, complex technology, centralized government, and writing. Of these, writing was traditionally the one most restricted geographically: until the expansions of Islam and of colonial Europeans, it was absent from Australia, Pacific islands, subequatorial Africa, and the whole New World except for a small part of Mesoamerica. As a result of that confined distribution, peoples who pride themselves on being civilized have always viewed writing as the sharpest distinction raising them above "barbarians" or "savages."

Knowledge brings power. Hence writing brings power to modern societies, by making it possible to transmit knowledge with far greater accuracy and in far greater quantity and detail, from more distant lands and more remote times. Of course, some peoples (notably the Incas) managed to administer empires without writing, and "civilized" peoples don't always defeat "barbarians," as Roman armies facing the Huns learned. But the European conquests of the Americas, Siberia, and Australia illustrate the typical recent outcome.

Writing marched together with weapons, microbes, and centralized